Research for Space Colonization: NASA Ralph Steckler/Space Grant Space Colonization Research and Technology Development Opportunity

Frank Prochaska, *Johnson Space Center*

The late Ralph Steckler, a successful assistant film director and photographer from Southern California, maintained a lifelong interest in space colonization. Mr. Steckler left the significant remainder of his estate to NASA "for the colonization of space because [he believed] this is for the betterment of mankind." NASA accepted the gift under the National Space Grant College and Fellowship Act, and established the program to implement Mr. Steckler's testamentary direction. For purposes of this endeavor, space colonization is understood to be the establishment of a broad range of human activity in space that, for the most part, is not reliant on Earth's resources.

The NASA Office of Education invited proposals for the NASA Ralph Steckler/Space Grant Space Colonization Research and Technology Development Opportunity (hereafter "Steckler/Space Grant Opportunity"). Each funded awardee addressed innovative, meaningful, and enduring research and technology development activities, aligned to a NASA research agenda that could enable space colonization or space settlement by providing a sustained human presence on the moon as a stepping-stone to future exploration of Mars.

The processes of innovation, research, and technology development frequently happen incrementally; therefore, the Steckler/Space Grant Opportunity provides implementation through three funding and development phases. Below are the number of awardees and monetary amounts with each phase.

Phase 1—Awarded January 2010

Number of awardees: 18
Award maximum: $70,000
Duration: 9 months

Phase II—Awarded January 2011

Number of awardees: 5
Award maximum: $250,000
Duration: 24 months

Phase III:

Number of awardees: 2
Award maximum: $275,000
Duration: 24 months

Below are project descriptions for (Ralph Steckler/ Space Grant Space Colonization Research and Technology Development Opportunity) Phase II awardees.

Title:
Flywheel Storage for Lunar Colonization
Technical Monitor:
Raymond Beach, Glenn Research Center
Principal Investigator:
David Atkinson, Idaho Space Grant Consortium

Project Description

Energy available on demand is absolutely necessary for long-term exploration and colonization of the moon. Energy generation is likely to be dominated by capture of solar energy and by nuclear energy sources. These and other sources of energy require storage to enable them to meet demand that varies with time of day and level of activity. Flywheels provide a reliable, efficient, and low-maintenance way to obtain continuous energy on demand. They have minimal shielding and require lighter payload for installation than batteries (NASA's current alternative) in the atmospheric vacuum, extreme temperature, and lunar surface's moderately elevated radiation levels. This project seeks to establish the scientific and technical merit and feasibility of using flywheel energy storage systems in support of human long-term exploration and colonization of the lunar surface. The project focuses on developing, verifying, and determining the characteristics of an idling iron energy loss reduction algorithm applied to an integrated hubless flywheel and motor generator design.

Title:
Acquisition of Planetary Samples During Human Surface Activities on the Moon and Beyond
Technical Monitor:
Jacob Bleacher, Goddard Space Flight Center
Principal Investigator:
Patricia Hynes, New Mexico Space Grant Consortium

Project Description

One of the crowning achievements of the Apollo Program was the return of approximately 382 kg (842 lbs.) of

Fig. 1. *Acquisition of planetary samples during human surface activities on the moon and beyond.*

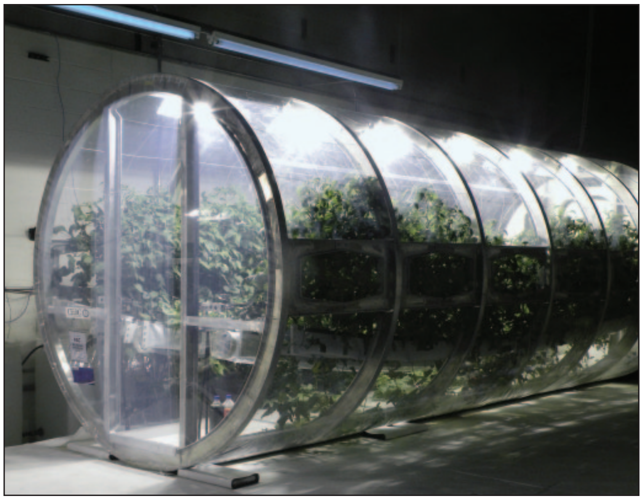

Fig. 2. *Lunar greenhouse.*

lunar material to Earth during six human missions. These samples provided a fundamental understanding of the origin and evolution of the Earth-moon system and the history of the early solar system. One of the major scientific activities that will occur during the future exploration of the moon and other planetary bodies (Mars, near-Earth objects) will be the acquisition of samples by humans. Past designs for exploration architectures (i.e., Constellation) had the capability for accommodating upwards of 100 kg (220 lbs.) of returned material, although increasing the capability for returning between 250 to 300 kg (551 to 387 lbs.) of material is scientifically valuable and have been investigated. Based on the Apollo 17 model, future sortie missions to the lunar surface have the capability of collecting 800 kg (1764 lbs.) of samples and lunar outpost activities will collect even more. This is significantly more than all proposed exploration architecture can return to Earth. Further, these sampling activities will acquire materials that are sensitive to both changes in environment and the techniques used in sampling and storage. Phase I of this study defined measurements and instrumentation required to enable humans to carefully select and "high-grade" scientifically important samples within the context of both sortie- and outpost-style surface activities and identified and demonstrate protocols and technologies necessary to preserve the integrity of environmentally sensitive and fragile samples. In Phase II, NASA will do the following: design, develop, and test a combined hand-held X-ray diffraction/X-ray fluorescence instrument that could be used for human "high-grading" of samples (in addition to robotic exploration of planetary surfaces); and establish a consortium to study material collected in Apollo-era sample containers. The former will increase the efficiency of human surface activities, whereas the latter will lead to improvements in the design of containers for environmentally sensitive samples (figure 1).

Title:

Lunar Greenhouse Prototype for Bio-regenerative Life Support Systems

Technical Monitor:

Raymond M. Wheeler, Kennedy Space Center

Principal Investigator:

Michael J. Drake, Arizona Space Grant Consortium

Project Description

Bioregenerative Life Support Systems (BLSS) are architected to revitalize the lunar habitat's atmosphere, recycle the crew's water, and generate a portion of the crew caloric intake and reduce resupply requirements. One component of the BLSS is the greenhouse subsystem. The Lunar Greenhouse (LGH) Prototype at the Controlled Environment Agriculture Center on the University of Arizona (UA) campus is comprised of a single modular deployable structure equipped with artificial lighting and growing system where plants grow in plastic envelops suspended from each end with nutrient solution flowing to the roots with very limited substrate.

The NASA Ralph Steckler Phase 1 funding focused on collecting data and understanding the LHG performance for BLSS of future lunar outposts with specific goals to demonstrate the polyculture growing systems, to determine the food production capability, the water, the carbon, energy balances, and to document the capabilities and weaknesses.

Phase II expands and enhances the UA-LGH facility to improve recycling capabilities of the gaseous, liquid, and solid phases of the system, increase food production efficiency (kg/unit time/resource input), and increase system fidelity. The objectives are to expand the number of LGH units to a maximum of no greater than 89.7 m^3 volume and 189 m^2 of growing area; enclose the interconnecting hallway so that the LGH units can provide for combinations of NASA food crops; incorporate water recycling, and evaluate the potential for solid waste recycling/composting; redesign the LGH1 plant microclimate to improve uniformity of its atmospheric aerodynamics; improve the monitoring, feedback control with additional non-contact sensing, and telepresence within a decision support system; and develop international cooperation by including faculty and students sponsored by foreign space agencies (i.e., Agencia Spatiale Italiano). See figure 2.

Title:
Nuclear Power for Space Colonization Research and Technology Development—Phase II
Technical Monitor:
Al Juhasz, Glenn Research Center
Principal Investigator:
Tom Blue and Gary Slater, Ohio Space Grant Consortium

Project Description

This project proposes to continue development of the Space Molten Salt Reactor that started in Phase I of the Ralph Steckler/Space Grant Space Colonization Research and Technology Development Opportunity with specific mission analysis, preliminary experimental verification, and rigorous computational models.

The Space Molten Salt Reactor will be developed primarily as an advanced nuclear surface power system for a space colony or scientific outpost. Specifically, development will be focused on electrical outpost above 100k to meet power needs associated with in-situ resource utilization and closed-loop life support. Meeting these power demands is essential to establishing a sustained human presence on the moon and eventually Mars.

To a lesser extent, the Space Molten Salt Reactor will be developed as an energy source for nuclear electric propulsion. Nuclear electric propulsion and nuclear surface power have similar design requirements, and nuclear electric propulsion supplements a colonization research agenda by assisting in crewed travel beyond near-Earth space.

Title:
Safety, Reliability and Reproducibility of Microbial Systems for Space Colonization
Technical Monitor:
John Hogan, NASA Ames Research Center
Principal Investigator:
Christopher House, Pennsylvania Space Grant Consortium

Project Description

Microbial reactors for waste treatment and food production are important parts of future life support systems. In Phase I research, the team verified the utility of three microbial components for inclusion in a life support system: a novel packed-bed, fixed-film anaerobic digester, a methantrophic co-culture for food production, and the novel Halomonas strain SP1 for secondary waste treatment at alkaline pH. In Phase II, the team will determine the safety, reliability, and reproducibility of these components to ensure predictable operation as part of a life support system. In Section 1 of the Phase II research, the team will construct small-scale anaerobic digesters and determine the reproducibility of biofilm community changes in response to operational stresses. The team will also examine methods of preserving biofilm for rapid start-up of a new anaerobic digester. Section 2 test will determine the reproducibility of the methanotrophic biomass as a food source, and experiment with a new type of bioreactor as well as various solid substrates as a way to improve growth rate and biomass density. In Section 3, the team will analyze the utility of strain SP1 for secondary waste treatment and possibly as an additional food source. Section 4 tests will be conducted to address safety of the system components by tracking the flow of proxy organisms for pathogens through each microbial reactor. In Phase III, the team will link the individual microbial reactors together into a continuously operated system to determine system losses and efficiency.